

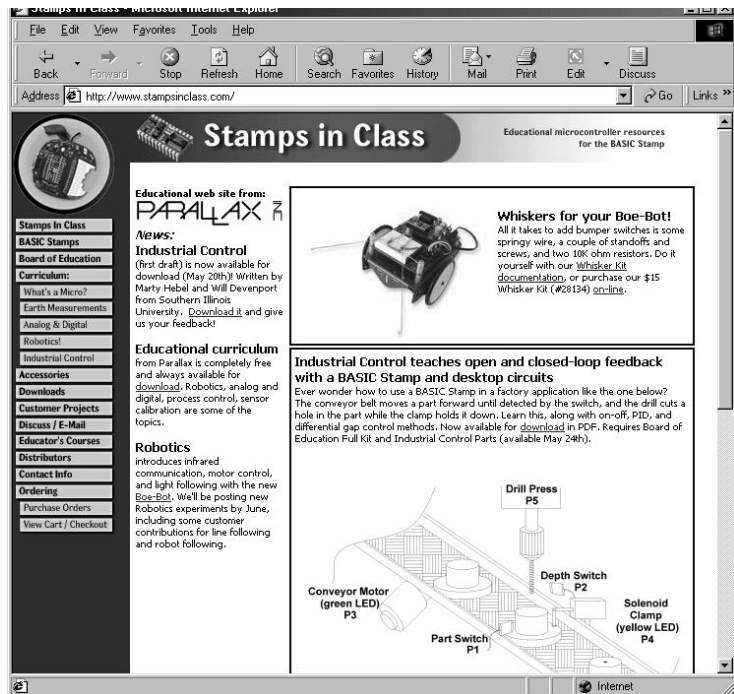
Appendix A: StampPlot Lite

StampPlot Lite is an application developed by SelmaWare Solutions for the Industrial Control series. The application allows plotting and capture of analog, digital and general data.

Downloading and Installing StampPlot Lite

StampPlot Lite may be downloaded from the Stamps in Class web site at <http://www.stampsinclass.com>. The program is installed by double-clicking on the setup.exe icon and accepting the default directories.

To download StampPlot Lite, click on the “Downloads” button on our web site and scroll down to the “Industrial Control” section.



Appendix A: StampPlot Lite

Data from the BASIC Stamp is processed in one of four ways by the application:

Analog Values

Any string sent beginning with a numeric value will be processed as an analog value and graphed.

```
Debug DEC 100, 13      'Plot the number 100
```

Digital Values

Any string sent beginning with '%' will be processed as digital values. A separate digital plot will be started for each binary value in the string. For example, "%1001" will plot four digital values. Up to a 9-bit value may be sent. Once digital plots are started, caution should be used to always send the same number of bits since the plots are position-order dependent.

```
Debug IBIN4 INC,13     'Plots 4 digital values
```

Control Settings

Any string beginning with '!' will be processed as a control setting. The various settings of the application may be controlled from the BASIC Stamp using specified control words and values, if required.

```
Debug "!AMAX 200",13   'Sets analog maximum for plot to 200
Debug "!RSET",13       'Resets the plot
```

Other Strings

All other strings simply will be added to the running message list box.

```
Debug "Hello world!",13
```

Note that each instance of data MUST end with a carriage return (13 or CR).

The steps for using BASIC Stamp programs with StampPlot Lite are as follows:

1. Start StampPlot Lite through your Start/Programs/StampPlot/StampPlot Lite icon.
2. Enter and run your BASIC Stamp program from the BASIC Stamp editor.
3. Close the blue BASIC Stamp debug window by clicking on the "close" box.
4. Select the COM port and click 'Connect' checkbox.
5. Click the 'Plot Data' checkbox.
6. Some programs may require you to reset the Board of Education (BASIC Stamp) to catch initial configuration and control settings. Do this by pressing the Reset button on the board.
7. Prior to downloading (running) another program to the BASIC Stamp, be sure to uncheck the StampPlot 'Connect' checkbox or your COM port will be locked by StampPlot Lite.

The plot will acquire analog and digital data and store it temporarily so that it may be resized or shifted on the screen. The number of data points collected is adjustable. Once the data points reach maximum, the plot must either be stopped or reset.

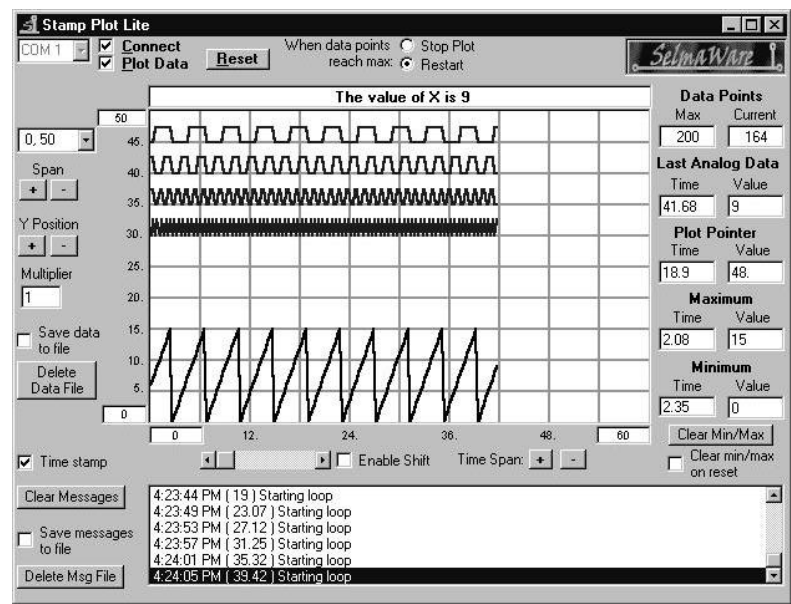
The following program will perform some configuration settings, continually plot and display the value of X on StampPlot, and plot the four digital bits of the value of X. Enter the program and use the steps above to test it with StampPlot Lite.

```
'Appendix A Program, StampPlot Example
'Configure StampPlot
Pause 500: Debug "!RSET",CR
Debug "!SPAN 0, 50",CR
Debug "!TSMP ON",CR
Debug "!TMAX 60",CR
Debug "!RSET",CR

X var Byte
Loop:
Debug "Starting loop", CR
For X = 0 to 15
Debug DEC X, CR
Debug IBIN4 X, CR
Debug "!USRS The value of X is ", DEC X, CR
  Pause 200
Next
Goto Loop
```

Appendix A: StampPlot Lite

Below is a screen shot of StampPlot Lite showing the above program plotted.



Tool Help

If a copy of StampPlot Lite is running on your computer, you may place the cursor over each control for 'Tool Text Help.' The following is a brief summary of each control. The BASIC Stamp programmable command, where applicable, is in brackets:

Top Section: General Controls



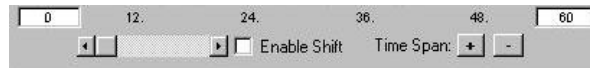
- Com 1: Drop down to select the applicable COM port.
- Connect: Connects the application to the selected COM port.
- Plot Data: Allows plotting of incoming data. Deselecting this control will stop the plotting of data but will allow messages and other actions to continue. [!PLOT ON/OFF]
- Reset: Clears the plot, resets to time 0, clears minimum and maximum value (optional). [!RSET]
- Stop Plot: When maximum data points are reached, the plot stops (Plot Data becomes unchecked). [!MAXS]
- Reset Plot: When maximum data points are reached, the plot resets. [!MAXR]
- User Status: (showing "The value of X is 9") Optional status messages from the BASIC Stamp may place data here. [!USRS message]

Left Section: Primarily for Setting the Analog Plot

- Span Drop-Down box: Allows a selection of pre-defined plot ranges. Use of the BASIC Stamp command !SPAN will add a range to this drop-down. [!SPAN minvalue, maxvalue]
- + and - buttons: Respectively double or halve the span. The minimum value does not change.
- Multiplier: Defines the amount incoming BASIC Stamp analog data will be multiplied by prior to plotting or saving to file. [!AMUL value]
- Save Data to File: Saves the incoming data to a text file in the application directory called "stampdat.txt." If time stamping is enabled, each record will be marked with the current system time and the number of seconds since the last reset. The value of the data point for analog and digital values will also be recorded. Each record will have the following form:
 - Time of day, seconds since reset, analog data point, analog value, digital data point, digital data value. Note that each record is comma delineated for importing into a spreadsheet, if desired.
 - *Note: Data is saved ONLY when ANALOG data arrives. To force saving when no analog data is recorded, debug a value such as zero (DEBUG DEC 0, CR).[!SAVD ON/OFF]*
- Delete Data File: Deletes "stampdat.txt." If data saving is enabled, the file will be re-created after deleting it. [!DELD]
- Analog Minimum and Maximum values: These may be manually changed. Tab off, or click another control, to set the new value. [!AMIN value !AMAX value <or> !SPAN minvalue, maxvalue]
- Time Stamp: Enables time stamping of messages and data to the file. It includes both the current time and seconds since the last reset. [!TSMP ON/OFF]
- Clear Messages: Clears the messages in the listbox. [!CLRM]
- Save messages to file: Saves messages to the file "stampmsg.txt" in the application directory. Messages will be saved the same way they appear in the message box. [!SAVM ON/OFF]
- Delete Msg file: Deletes "stampmsg.txt" in the application directory. If the "Save Messages..." is enabled, the file will be re-created. [!DELM]

The screenshot shows the StampPlot Lite control panel. At the top, there is a 'Span' drop-down menu currently set to '0, 50'. Below it are '+' and '-' buttons for adjusting the span. To the right of these buttons is a vertical scale from 0 to 50. Below the span controls is a 'Y Position' section with '+' and '-' buttons and a corresponding vertical scale from 0 to 45. Below that is a 'Multiplier' section with a text box containing '1' and a vertical scale from 0 to 25. Further down is a 'Save data to file' checkbox, which is checked, and a 'Delete Data File' button. Below that is a 'Time stamp' checkbox, which is also checked, and a 'Clear Messages' button. At the bottom is a 'Save messages to file' checkbox, which is unchecked, and a 'Delete Msg File' button.

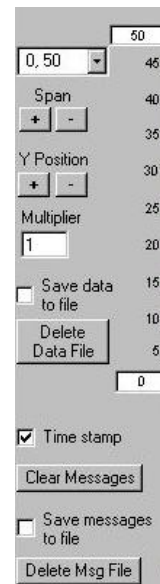
Bottom Section: Plot Shift and Time Span



- The minimum and maximum times of the plot may be set manually. Tab-off or click another control to apply the value. [!TMIN value and !TMAX value]
- Scroll Bar: If the plot extends beyond the current limits, the scroll bar may be used to reposition the plot (if collecting data, Enable Shift must be on).
- Enable Shift: Allows the plot to shift automatically when maximum plotted time is exceeded. Also enables operation of the scroll bar when collecting data. Note: Shifting of the plot during data collection may cause time errors in the data as the plot refreshes. [!SHFT ON/OFF]
- +/-: Respectively doubles or halves the time span of the plot. The minimum value of the plot will not change.

Right Section: Y Axis Control and Data File Saving

- Data Points: To allow the plot to be manipulated, data is stored in memory. The maximum number of points (either analog or digital) that may be recorded is set by Max. 'Current' displays the current data point being stored. Once the maximum is reached, the plot will either reset or stop, depending on the configuration.
- Last Analog Data: Displays the time since reset and the last analog value plotted.
- Plot Pointer: Moving the plot pointer on the display shows the current analog value and time for that point on the plot.
- Maximum: Records the maximum analog value and the time it was reached.
- Minimum: Records the minimum analog value and the time it was reached.
- Clear Min/Max: Clears the recorded minimum and maximum values. [!CLMM]
- Clear min/max on reset: Allows a reset to clear the minimum and maximum values. [!CMMR]



Appendix A: StampPlot Lite

Display Control and Zoom

- Moving the cursor on the plot will set the plot pointer time and value to the current position.
- Double-clicking the plot will shift display modes from yellow to white background and thin lines to thick lines for better printing (ALT-Print Screen to capture form to the clipboard) and projected display.
- Shift-Click (hold) and Drag allows you to specify an area of the plot to zoom.

BASIC Stamp Control and Configuration Commands

The majority of the plot configuration and controls may be set from within the BASIC Stamp program. To use these commands, simply debug from the BASIC Stamp. All commands must end with a CR (ASCII 13): DEBUG "PLOT ON", CR.

Command	Description
!TITL message	Sets the title of the form to the message
!USRS message	Sets the User Status box to display the message
!BELL	Sounds the bell on the PC
!AMAX value	Sets the plot maximum analog value
!AMIN value	Sets the plot minimum analog value
!SPAN minValue, maxValue	Sets the plots analog maximum and minimum as above (also adds the range to the Range Drop-Down box).
!AMUL value	Sets the value to multiply incoming data by
!TMAX value	Sets the plot maximum time (seconds)
!TMIN value	Sets the plot minimum time (seconds)
!PNTS value	Sets the number of data points to collect
!PLOT ON/OFF	Enables/disables the plotting of data
!RSET	Resets the plot and all data
!CLRM	Clears the message list
!CLMM	Clears the min/max recorded values
!CMMR ON/OFF	Enables/Disables clearing of Min/Max recorded values on reset
!MAXS	Sets the plot to STOP when data points are full
!MAXR	Sets the plot to RESET when data points are full
!SHFT ON/OFF	Enables/disables the plot from shifting when recording data (may cause a loss of data accuracy if enabled)
!TSMP ON/OFF	Enables time stamping of list messages; messages and data saved to files
!SAVD ON/OFF	Enables saving of analog and digital data to files
!SAVM ON/OFF	Enables saving of messages to a file
!DELD	Deletes the saved data file
!DELM	Deletes the saved message file

Additional Application Notes

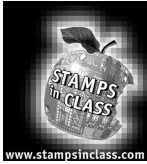
The amount of the plot that is used is dependent on the number of data points and the rate at which they are transmitted. For example, if you wish 60 seconds of data to fill the screen and are transmitting from the BASIC Stamp at a maximum rate of 100 msec (Pause 100 + processing time): $60/.1 = 600$ data points.

The application needs a minimum regular pause in the reception of data for complete processing. A pause of 10 msec is typically sufficient for a fairly fast computer. If the application senses it cannot keep up with incoming data, a message box will appear and the application will disconnect. Some indications that the computer cannot keep up are: garbled data, no plotting, and the inability to affect any controls (locks up).

The greater the number of data points and the higher the current data point, the longer the plot will take to respond to plot shifts as it redraws. For faster, reliable configuration from the BASIC Stamp on initial power up or resetting, the following is recommended:

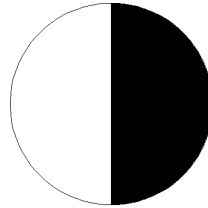
- Pause for 500msec at the start to allow StampPlot's buffer to clear.
- Perform a StampPlot RESET (!RSET) prior to making configuration changes to allow the data points to be cleared so redrawing is not performed.
- Reset (!RSET) at the end of the configuration resets the plot to time 0.

As with any application, the best way to learn it is to play. Have fun!

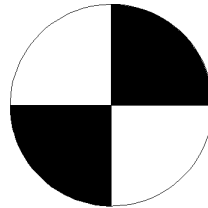


Appendix B: Fan Encoder Printouts

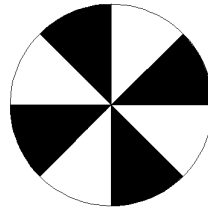
These printouts are full size, and should be an ideal fit for your fan used as a digital switch in Experiment #2.



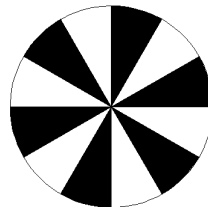
1 cycle/revolution



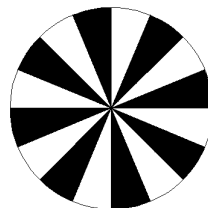
2 cycles/revolution



4 cycles/revolution

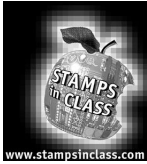


6 cycles/revolution



8 cycles/revolution

Appendix B: Fan Encoder Printouts



Appendix C: Potter Brumfield SSR Datasheet

Appendix C consists of the Potter Brumfield “Hockey Puck” Solid State Relay. Their datasheets may be downloaded from <http://www.pandbrelays.com/>.



SSRT series

“Hockey Puck”
Solid State Relay With
Snubberless Triac Output

File E29244
File E29244 UL Recognized for Canada

- Features**
- Standard “hockey puck” package.
 - Exposed ceramic base plate for reduced thermal resistance.
 - Floating terminal design.
 - Low cost snubberless triac outputs.
 - 10A & 25A rms versions.
 - AC & DC input versions.
 - 4000V rms isolation.

Engineering Data
Form: 1 Form A (SPST-NO).
Duty: Continuous.
Isolation: 4000V rms minimum, input - output.
Isolation Resistance: 10^{10} ohms @ 500VDC minimum.
Capacitance: 10 pf maximum (input to output).
Temperature Range:
 Storage: -40°C to +120°C
 Operating Temperature: -25°C to + 80°C
Case Material: Plastic, UL rated 94V-0.
Base Plate Material: Ceramic.
Case and Mounting: Refer to outline dimension.
Termination: Refer to outline dimension.
Approximate Weight: 3.5 oz. (98g).

Ordering Information

	Sample Part Number ▶	SSRT	-240	D	10
1. Basic Series:	SSRT = “hockey puck” triac output solid state relay				
2. Line Voltage:	240 = 24-240 VAC				
3. Input Type & Voltage:	A = 90-280 VAC/VDC linear D = 3-32 VDC constant current				
4. Maximum Switching Rating:	10 = .05-10A rms, mounted to heatsink 25 = .05-25A rms, mounted to heatsink				

Stock Items – The following items are normally maintained in stock for immediate delivery.

SSRT240A10 SSRT240D10
SSRT240A25 SSRT240D25

Input Specifications

Parameter	AC/DC Input/AC Output	DC Input/AC Output
Control Voltage Range V_{IH}	90-280VAC/VDC	3-32VDC
Must Operate Voltage $V_{N(ON)}$ (Max.)	90VAC/VDC	3VDC
Must Release Voltage $V_{N(REL)}$ (Min.)	10VAC/VDC	1VDC
Input Current	15mA Max. @ 90VAC	15mA Max. @ 5VDC



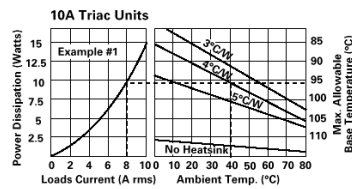
Parameter	Conditions	Units	SSRT-240A10 & SSRT-240D10	SSRT-240A25 & SSRT-240D25
Load Voltage Range V_L		V rms	24-240	
Repetitive Blocking Voltage (Min.)		V peak	≥600	
Load Current Range I_L *	Resistive	A rms	.05-10	.05-25
Single Cycle Surge Current (Min.)		A peak	100	200
Leakage Current (Off-State) (Max.)	$f = 60 \text{ Hz}$, $V_L = \text{Nom.}$ (120 or 240 V rms)	mA rms	0.5	
On-State Voltage Drop (Max.)	$I_L = \text{Max.}$	V peak	1.7	
Static dv/dt (Off-State) (Min.)		V/μs	200	
Thermal Resistance, Junction to Case ($R_{\theta JA}$) (Max.)		°C/W	0.6	0.6
Turn-On Time (Max.)	$f = 60 \text{ Hz}$	ms	8.3	
Turn-Off Time (Max.)	$f = 60 \text{ Hz}$	ms	8.3	
$I^2 t$ Rating	$t = 8.3 \text{ ms}$	A ² Sec.	60	260
Load Power Factor Rating	$I_L = \text{Max.}$		0.5-1.0	

*See Derating Curves

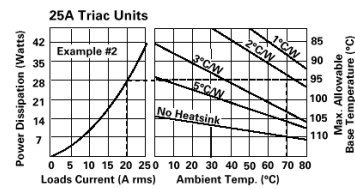
Electrical Characteristics (Thermal Derating Curves)

How To Use These Curves

Knowing maximum load current and maximum ambient temperature, use derating curves to determine the minimum required heat sink and maximum allowable base plate temperature. On left hand power dissipation curve, locate the point corresponding to maximum load current. Extend a line to the right from that point to the intersection of vertical line on right hand chart corresponding to maximum ambient temperature. From heat sink curve, read directly or extrapolate required heat sink size. Extend the line farther to the right and read on the right hand scale the maximum allowable base plate temperature.



Example #1:
Given: $I_L = 8A \text{ rms}$ @ 40°C
Find: Heatsink required
Solution: From 10A curve
 Heatsink = 4°C/W



Example #2:
Given: $I_L = 20A \text{ rms}$ @ 70°C
Find: Required heatsink
Solution: Heatsink = 2°C/W

Heatsink Dimensions

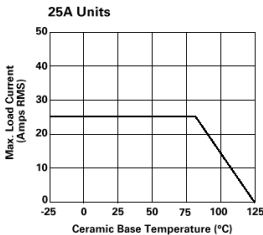
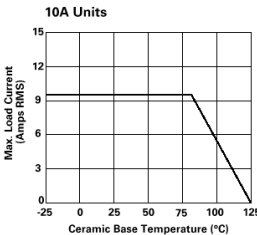
- We recommend that solid State Relay Modules be mounted to a heatsink sufficient to maintain the module's base temperature at less than 85°C under worst case ambient temperature and load conditions.
- The heatsink mounting surface should be a smooth (30-40 micro-inch finish), flat (30-40 micro-inch flatness across mating area), un-painted surface which is clean and free of oxidation.
- An even coating of thermal compound (Dow Corning DC340 or equivalent) should be applied to both the heatsink and module mounting surfaces and spread to a uniform depth of .002" to eliminate all air pockets.
- The module should be mounted to the heatsink using two#10 screws. The mounting screws should be torqued to 10 inch-pounds by alternately tightening the screws one quarter turn at a time.

Appendix C: Potter Brumfield SSR Datasheet

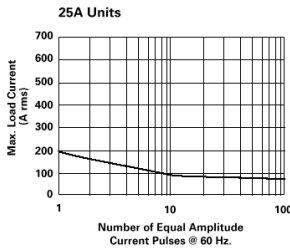
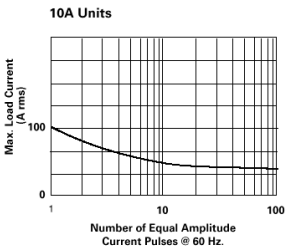


tyco Electronics

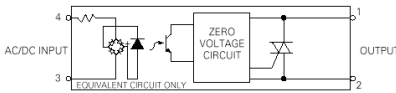
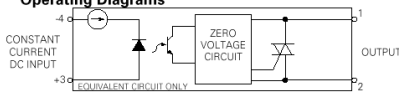
Load Current vs. Base Temperature



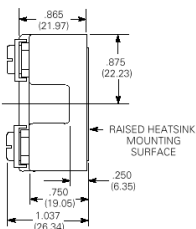
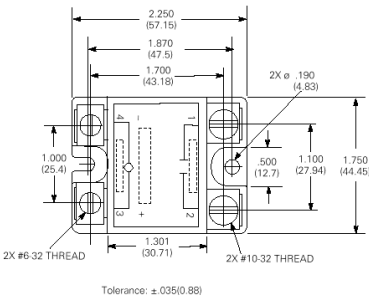
Allowable Peak Surge vs. Duration/Expected Lifetime



Operating Diagrams

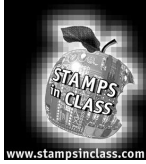


Outline Dimensions



Tyco Electronics
700 Westpark Drive
Peachtree City, GA 30269-1498

Specifications and availability subject to change without notice.
13C7778 Printed in U.S.A. IH/2-00



Appendix D: National Semiconductor LM34 Datasheet

Appendix D consists of the National Semiconductor LM34 datasheet. This appendix includes the first five (5) pages of the 12-page datasheet. Should you wish to see more applications of the LM34 than are shown in this datasheet, the entire document may be downloaded from <http://www.national.com/ds/LM/LM34.pdf>.



National Semiconductor

July 1999

LM34

Precision Fahrenheit Temperature Sensors

General Description

The LM34 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Fahrenheit temperature. The LM34 thus has an advantage over linear temperature sensors calibrated in degrees Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Fahrenheit scaling. The LM34 does not require any external calibration or trimming to provide typical accuracies of $\pm 1/2^\circ\text{F}$ at room temperature and $\pm 1 1/2^\circ\text{F}$ over a full -50 to $+300^\circ\text{F}$ temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM34's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies or with plus and minus supplies. As it draws only $75\text{ }\mu\text{A}$ from its supply, it has very low self-heating, less than 0.2°F in still air. The LM34 is rated to operate over a -50° to $+300^\circ\text{F}$ temperature range, while the LM34C is rated for a -40° to $+230^\circ\text{F}$ range (0°F with improved accuracy). The LM34 series is available packaged in

hermetic TO-46 transistor packages, while the LM34C, LM34CA and LM34D are also available in the plastic TO-92 transistor package. The LM34D is also available in an 8-lead surface mount small outline package. The LM34 is a complement to the LM35 (Centigrade) temperature sensor.

Features

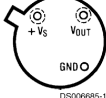
- Calibrated directly in degrees Fahrenheit
- Linear $+10.0\text{ mV}/^\circ\text{F}$ scale factor
- 1.0°F accuracy guaranteed (at $+77^\circ\text{F}$)
- Rated for full -50° to $+300^\circ\text{F}$ range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 5 to 30 volts
- Less than $90\text{ }\mu\text{A}$ current drain
- Low self-heating, 0.18°F in still air
- Nonlinearity only $\pm 0.5^\circ\text{F}$ typical
- Low-impedance output, 0.4Ω for 1 mA load

Connection Diagrams

TO-46

Metal Can Package

(Note 1)

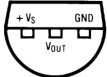


DS006685-1

Order Numbers LM34H, LM34AH, LM34CH, LM34CAH or LM34DH
See NS Package Number H03H

TO-92

Plastic Package



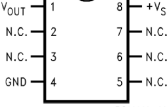
DS006685-2

Order Number LM34CZ, LM34CAZ or LM34DZ
See NS Package Number Z03A

SO-8

Small Outline

Molded Package



DS006685-20

N.C. = No Connection

Top View

Order Number LM34DM

See NS Package Number M08A

Note 1: Case is connected to negative pin (GND).

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Typical Applications

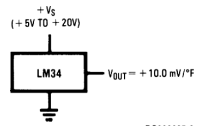


FIGURE 1. Basic Fahrenheit Temperature Sensor
(+5° to +300°F)

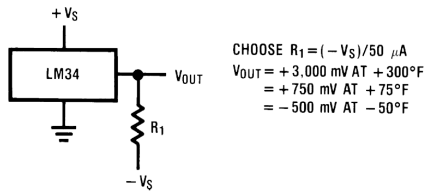


FIGURE 2. Full-Range Fahrenheit Temperature Sensor

Appendix D: LM34 Manufacturer's Datasheet

Absolute Maximum Ratings (Note 11)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage	+35V to -0.2V
Output Voltage	+6V to -1.0V
Output Current	10 mA
Storage Temperature,	
TO-46 Package	-76°F to +356°F
TO-92 Package	-76°F to +300°F
SO-8 Package	-65°C to +150°C
ESD Susceptibility (Note 12)	800V
Lead Temp.	

TO-46 Package	
(Soldering, 10 seconds)	+300°C
TO-92 Package	
(Soldering, 10 seconds)	+260°C
SO Package (Note 13)	
Vapor Phase (60 seconds)	215°C
Infrared (15 seconds)	220°C
Specified Operating Temp. Range (Note 3)	
	T_{MIN} to T_{MAX}
LM34, LM34A	-50°F to +300°F
LM34C, LM34CA	-40°F to +230°F
LM34D	+32°F to +212°F

DC Electrical Characteristics (Notes 2, 7)

Parameter	Conditions	LM34A			LM34CA			Units (Max)
		Typical	Tested Limit (Note 5)	Design Limit (Note 6)	Typical	Tested Limit (Note 5)	Design Limit (Note 6)	
Accuracy (Note 8)	T _A = +77°F	±0.4	±1.0		±0.4	±1.0		°F
	T _A = 0°F	±0.6			±0.6		±2.0	°F
	T _A = T _{MAX}	±0.8	±2.0		±0.8	±2.0		°F
	T _A = T _{MIN}	±0.8	±2.0		±0.8		±3.0	°F
Nonlinearity (Note 9)	T _{MIN} ≤ T _A ≤ T _{MAX}	±0.35		±0.7	±0.30		±0.6	°F
Sensor Gain (Average Slope)	T _{MIN} ≤ T _A ≤ T _{MAX}	+10.0	+9.9, +10.1		+10.0		+9.9, +10.1	mV/°F, min mV/°F, max
Load Regulation (Note 4)	T _A = +77°F T _{MIN} ≤ T _A ≤ T _{MAX} 0 ≤ I _L ≤ 1 mA	±0.4 ±0.5	±1.0	±3.0	±0.4 ±0.5	±1.0	±3.0	mV/mA mV/mA
Line Regulation (Note 4)	T _A = +77°F 5V ≤ V _S ≤ 30V	±0.01 ±0.02	±0.05	±0.1	±0.01 ±0.02	±0.05	±0.1	mV/V mV/V
Quiescent Current (Note 10)	V _S = +5V, +77°F	75	90		75	90		μA
	V _S = +5V	131		160	116		139	μA
	V _S = +30V, +77°F	76	92		76	92		μA
	V _S = +30V	132		163	117		142	μA
Change of Quiescent Current (Note 4)	4V ≤ V _S ≤ 30V, +77°F	+0.5	2.0		0.5	2.0		μA
	5V ≤ V _S ≤ 30V	+1.0		3.0	1.0		3.0	μA
Temperature Coefficient of Quiescent Current		+0.30		+0.5	+0.30		+0.5	μA/°F
Minimum Temperature for Rated Accuracy	In circuit of Figure 1, I _L = 0	+3.0		+5.0	+3.0		+5.0	°F
Long-Term Stability	T _J = T _{MAX} for 1000 hours	±0.16			±0.16			°F

Note 2: Unless otherwise noted, these specifications apply: -50°F ≤ T_J ≤ +300°F for the LM34 and LM34A; -40°F ≤ T_J ≤ +230°F for the LM34C and LM34CA; and +32°F ≤ T_J ≤ +212°F for the LM34D. V_S = +5 Vdc and I_{LOAD} = 50 μA in the circuit of Figure 2; +6 Vdc for LM34 and LM34A for 230°F ≤ T_J ≤ 300°F. These specifications also apply from +5°F to T_{MAX} in the circuit of Figure 1.

Note 3: Thermal resistance of the TO-46 package is 720°F/W junction to ambient and 43°F/W junction to case. Thermal resistance of the TO-92 package is 324°F/W junction to ambient. Thermal resistance of the small outline molded package is 400°F/W junction to ambient. For additional thermal resistance information see table in the Typical Applications section.

Note 4: Regulation is measured at constant junction temperature using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

Note 5: Tested limits are guaranteed and 100% tested in production.

Note 6: Design limits are guaranteed (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

Note 7: Specification in **BOLDFACE TYPE** apply over the full rated temperature range.

DC Electrical Characteristics (Notes 2, 7) (Continued)

Note 8: Accuracy is defined as the error between the output voltage and 10 mV/°F times the device's case temperature at specified conditions of voltage, current, and temperature (expressed in °F).

Note 9: Nonlinearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line over the device's rated temperature range.

Note 10: Quiescent current is defined in the circuit of *Figure 1*.

Note 11: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions (Note 2).

Note 12: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

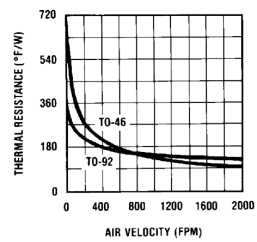
Note 13: See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" or the section titled "Surface Mount" found in a current National Semiconductor Linear Data Book for other methods of soldering surface mount devices.

DC Electrical Characteristics (Notes 2, 7)

Parameter	Conditions	LM34			LM34C, LM34D			Units (Max)
		Typical	Tested Limit (Note 5)	Design Limit (Note 6)	Typical	Tested Limit (Note 5)	Design Limit (Note 6)	
Accuracy, LM34, LM34C (Note 8)	$T_A = +77^\circ\text{F}$	±0.8	±2.0		±0.8	±2.0		°F
	$T_A = 0^\circ\text{F}$	±1.0			±1.0		±3.0	°F
	$T_A = T_{\text{MAX}}$	±1.6	±3.0		±1.6		±3.0	°F
	$T_A = T_{\text{MIN}}$	±1.6		±3.0	±1.6		±4.0	°F
Accuracy, LM34D (Note 8)	$T_A = +77^\circ\text{F}$				±1.2	±3.0		°F
	$T_A = T_{\text{MAX}}$				±1.8		±4.0	°F
	$T_A = T_{\text{MIN}}$				±1.8		±4.0	°F
Nonlinearity (Note 9)	$T_{\text{MIN}} \leq T_A \leq T_{\text{MAX}}$	±0.6		±1.0	±0.4		±1.0	°F
Sensor Gain (Average Slope)	$T_{\text{MIN}} \leq T_A \leq T_{\text{MAX}}$	+10.0	+9.8, +10.2		+10.0		+9.8, +10.2	mV/°F, min mV/°F, max
Load Regulation (Note 4)	$T_A = +77^\circ\text{F}$	±0.4	±2.5		±0.4	±2.5		mV/mA
	$T_{\text{MIN}} \leq T_A \leq +150^\circ\text{F}$ $0 \leq I_L \leq 1 \text{ mA}$	±0.5		±6.0	±0.5		±6.0	mV/mA
Line Regulation (Note 4)	$T_A = +77^\circ\text{F}$	±0.01	±0.1		±0.01	±0.1		mV/V
	$5\text{V} \leq V_S \leq 30\text{V}$	±0.02		±0.2	±0.02		±0.2	mV/V
Quiescent Current (Note 10)	$V_S = +5\text{V}, +77^\circ\text{F}$	75	100		75	100		μA
	$V_S = +5\text{V}$	131		176	116		154	μA
	$V_S = +30\text{V}, +77^\circ\text{F}$	76	103		76	103		μA
	$V_S = +30\text{V}$	132		181	117		159	μA
Change of Quiescent Current (Note 4)	$4\text{V} \leq V_S \leq 30\text{V}, +77^\circ\text{F}$	+0.5	3.0		0.5	3.0		μA
	$5\text{V} \leq V_S \leq 30\text{V}$	+1.0		5.0	1.0		5.0	μA
Temperature Coefficient of Quiescent Current		+0.30		+0.7	+0.30		+0.7	μA/°F
Minimum Temperature for Rated Accuracy	In circuit of <i>Figure 1</i> , $I_L = 0$	+3.0		+5.0	+3.0		+5.0	°F
Long-Term Stability	$T_i = T_{\text{MAX}}$ for 1000 hours	±0.16			±0.16			°F

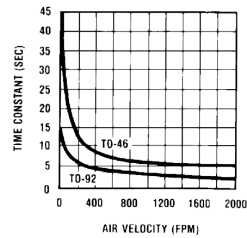
Typical Performance Characteristics

**Thermal Resistance
Junction to Air**



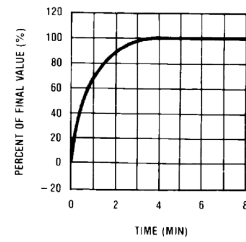
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Thermal Time Constant



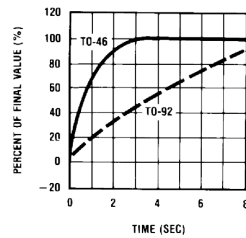
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**Thermal Response in
Still Air**



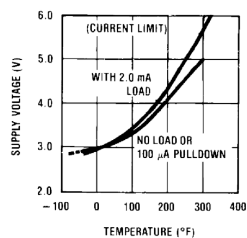
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**Thermal Response in
Stirred Oil Bath**



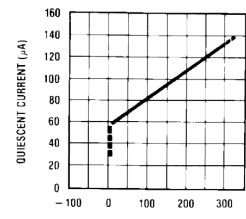
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**Minimum Supply Voltage
vs. Temperature**



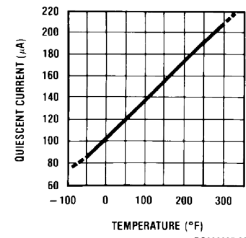
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**Quiescent Current vs.
Temperature
(In Circuit of Figure 1)**



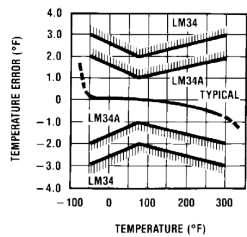
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**Quiescent Current vs. Temp-
erature (In Circuit of Figure 2;
 $-V_S = -5\text{V}$, $R_1 = 100\text{k}$)**



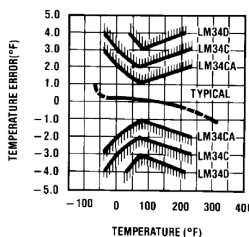
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**Accuracy vs. Temperature
(Guaranteed)**

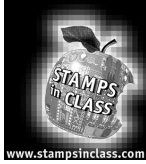


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**Accuracy vs. Temperature
(Guaranteed)**



DS006685-30



Appendix E: National Semiconductor LM358 Datasheet

Appendix D consists of the National Semiconductor LM358 datasheet. This appendix includes the first five (5) pages of the 23-page datasheet. Should you wish to see more applications of the LM358 than are shown in this datasheet, the entire document may be downloaded from <http://www.national.com/ds/LM/LM158.pdf>.



January 2000

LM158/LM258/LM358/LM2904

Low Power Dual Operational Amplifiers

General Description

The LM158 series consists of two independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

Application areas include transducer amplifiers, dc gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM158 series can be directly operated off of the standard +5V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional $\pm 15V$ power supplies.

The LM358 is also available in a chip sized package (8-Bump micro SMD) using National's micro SMD package technology.

Unique Characteristics

- In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though operated from only a single power supply voltage.
- The unity gain cross frequency is temperature compensated.
- The input bias current is also temperature compensated.

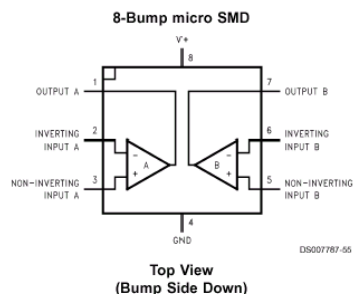
Advantages

- Two internally compensated op amps
- Eliminates need for dual supplies
- Allows direct sensing near GND and V_{OUT} also goes to GND
- Compatible with all forms of logic
- Power drain suitable for battery operation
- Pin-out same as LM1558/LM1458 dual op amp

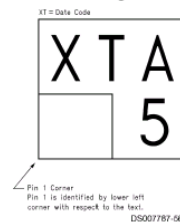
Features

- Available in 8-Bump micro SMD chip sized package, (See AN-1112)
- Internally frequency compensated for unity gain
- Large dc voltage gain: 100 dB
- Wide bandwidth (unity gain): 1 MHz (temperature compensated)
- Wide power supply range:
 - Single supply: 3V to 32V
 - or dual supplies: $\pm 1.5V$ to $\pm 16V$
- Very low supply current drain (500 μA)—essentially independent of supply voltage
- Low input offset voltage: 2 mV
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Large output voltage swing: 0V to $V^+ - 1.5V$

Connection Diagrams



micro SMD Marking Orientation

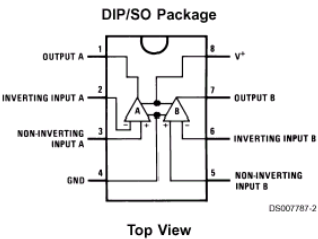
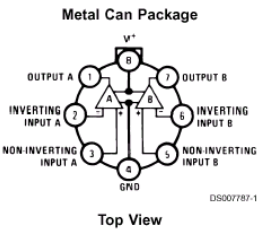


Bumps are numbered counter-clockwise.

Top View

LM158/LM258/LM358/LM2904

Connection Diagrams (Continued)



Ordering Information

Package	Temperature Range				NSC Drawing
	-55°C to 125°C	-25°C to 85°C	0°C to 70°C	-40°C to 85°C	
SO-8			LM358AM LM358M	LM2904M	M08A
8-Pin Molded DIP			LM358AN LM358N	LM2904N	N08E
8-Pin Ceramic DIP	LM158AJ/883(Note 1) LM158J/883(Note 1) LM158J LM158AJLQML(Note 2) LM158AJQMLV(Note 2)				J08A
TO-5, 8-Pin Metal Can	LM158AH/883(Note 1) LM158H/883(Note 1) LM158AH LM158H LM158AHLQML(Note 2) LM158AHLQMLV(Note 2)	LM258H	LM358H		H08C
8-Bump micro SMD			LM358BP LM358BPX		BPA08AAA

Note 1: LM158 is available per SMD #5962-8771001
LM158A is available per SMD #5962-8771002
Note 2: See STD Mil DWG 5962L87710 for Radiation Tolerant Devices

Appendix E: LM358 Manufacturer's Datasheet

Absolute Maximum Ratings (Note 11)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

	LM158/LM258/LM358 LM158A/LM258A/LM358A	LM2904
Supply Voltage, V^*	32V	26V
Differential Input Voltage	32V	26V
Input Voltage	-0.3V to +32V	-0.3V to +26V
Power Dissipation (Note 3)		
Molded DIP	830 mW	830 mW
Metal Can	550 mW	
Small Outline Package (M)	530 mW	530 mW
micro SMD	435mW	
Output Short-Circuit to GND (One Amplifier) (Note 4) $V^* \leq 15V$ and $T_A = 25^\circ C$	Continuous 50 mA	Continuous 50 mA
Input Current ($V_{IN} < -0.3V$) (Note 5)		
Operating Temperature Range		
LM358	0°C to +70°C	-40°C to +85°C
LM258	-25°C to +85°C	
LM158	-55°C to +125°C	
Storage Temperature Range	-65°C to +150°C	-65°C to +150°C
Lead Temperature, DIP (Soldering, 10 seconds)	260°C	260°C
Lead Temperature, Metal Can (Soldering, 10 seconds)	300°C	300°C
Soldering Information		
Dual-In-Line Package		
Soldering (10 seconds)	260°C	260°C
Small Outline Package		
Vapor Phase (60 seconds)	215°C	215°C
Infrared (15 seconds)	220°C	220°C
See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.		
ESD Tolerance (Note 12)	250V	250V

Electrical Characteristics

$V^* = +5.0V$, unless otherwise stated

Parameter	Conditions	LM158A			LM358A			LM158/LM258			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	(Note 7), $T_A = 25^\circ C$	1	2		2	3		2	5		mV
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$, $T_A = 25^\circ C$, $V_{CM} = 0V$, (Note 8)	20	50		45	100		45	150		nA
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, $V_{CM} = 0V$, $T_A = 25^\circ C$	2	10		5	30		3	30		nA
Input Common-Mode Voltage Range	$V^* = 30V$, (Note 9) (LM2904, $V^* = 26V$), $T_A = 25^\circ C$	0	$V^*-1.5$		0	$V^*-1.5$		0	$V^*-1.5$		V
Supply Current	Over Full Temperature Range $R_L = \infty$ on All Op Amps $V^* = 30V$ (LM2904 $V^* = 26V$) $V^* = 5V$	1	2		1	2		1	2		mA
		0.5	1.2		0.5	1.2		0.5	1.2		mA

LM158/LM258/LM358/LM2904

Electrical CharacteristicsV⁺ = +5.0V, unless otherwise stated

Parameter	Conditions	LM358			LM2904			Units
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	(Note 7), T _A = 25°C		2	7		2	7	mV
Input Bias Current	I _{IN(+)} or I _{IN(-)} , T _A = 25°C, V _{CM} = 0V, (Note 8)		45	250		45	250	nA
Input Offset Current	I _{IN(+)} - I _{IN(-)} , V _{CM} = 0V, T _A = 25°C		5	50		5	50	nA
Input Common-Mode Voltage Range	V ⁺ = 30V, (Note 9) (LM2904, V ⁺ = 26V), T _A = 25°C	0		V ⁺ -1.5	0		V ⁺ -1.5	V
Supply Current	Over Full Temperature Range							
	R _L = ∞ on All Op Amps							
	V ⁺ = 30V (LM2904 V ⁺ = 26V) V ⁺ = 5V		1 0.5	2 1.2		1 0.5	2 1.2	mA mA

Electrical CharacteristicsV⁺ = +5.0V, (Note 6), unless otherwise stated

Parameter	Conditions	LM158A			LM358A			LM158/LM258			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Large Signal Voltage Gain	V ⁺ = 15V, T _A = 25°C, R _L ≥ 2 kΩ, (For V _O = 1V to 11V)	50	100		25	100		50	100		V/mV
Common-Mode Rejection Ratio	T _A = 25°C, V _{CM} = 0V to V ⁺ -1.5V	70	85		65	85		70	85		dB
Power Supply Rejection Ratio	V ⁺ = 5V to 30V (LM2904, V ⁺ = 5V to 26V), T _A = 25°C	65	100		65	100		65	100		dB
Amplifier-to-Amplifier Coupling	f = 1 kHz to 20 kHz, T _A = 25°C (Input Referred), (Note 10)	-120			-120			-120			dB
Output Current	Source V _{IN} ⁺ = 1V, V _{IN} ⁻ = 0V, V ⁺ = 15V, V _O = 2V, T _A = 25°C	20	40		20	40		20	40		mA
	Sink V _{IN} ⁻ = 1V, V _{IN} ⁺ = 0V V ⁺ = 15V, T _A = 25°C, V _O = 2V	10	20		10	20		10	20		mA
	V _{IN} ⁻ = 1V, V _{IN} ⁺ = 0V T _A = 25°C, V _O = 200 mV, V ⁺ = 15V	12	50		12	50		12	50		μA
Short Circuit to Ground	T _A = 25°C, (Note 4), V ⁺ = 15V	40	60		40	60		40	60		mA
Input Offset Voltage	(Note 7)		4			5			7		mV
Input Offset Voltage Drift	R _S = 0Ω	7	15		7	20		7			μV/°C
Input Offset Current	I _{IN(+)} - I _{IN(-)}		30			75			100		nA
Input Offset Current Drift	R _S = 0Ω	10	200		10	300		10			pA/°C
Input Bias Current	I _{IN(+)} or I _{IN(-)}	40	100		40	200		40	300		nA
Input Common-Mode Voltage Range	V ⁺ = 30 V, (Note 9) (LM2904, V ⁺ = 26V)	0		V ⁺ -2	0		V ⁺ -2	0		V ⁺ -2	V

Appendix E: LM358 Manufacturer's Datasheet

LM158/LM258/LM358/LM2904

Electrical Characteristics (Continued)

V* = +5.0V, (Note 6), unless otherwise stated

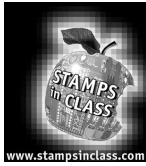
Parameter		Conditions	LM158A			LM358A			LM158/LM258			Units
			Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Large Signal Voltage Gain		V* = +15V (V _O = 1V to 11V) R _L ≥ 2 kΩ	25			15			25			V/mV
Output Voltage Swing	V _{OH}	V* = +30V (LM2904, V* = 26V) R _L = 2 kΩ	26			26			26			V
	V _{OL}	R _L = 10 kΩ	27	28		27	28		27	28		V
		V* = 5V, R _L = 10 kΩ	5			5			5			mV
Output Current	Source	V _{IN} ⁺ = +1V, V _{IN} ⁻ = 0V, V* = 15V, V _O = 2V	10	20		10	20		10	20		mA
	Sink	V _{IN} ⁻ = +1V, V _{IN} ⁺ = 0V, V* = 15V, V _O = 2V	10	15		5	8		5	8		mA

Electrical Characteristics

V* = +5.0V, (Note 6), unless otherwise stated

Parameter		Conditions	LM358			LM2904			Units	
			Min	Typ	Max	Min	Typ	Max		
Large Signal Voltage Gain		V* = 15V, T _A = 25°C, R _L ≥ 2 kΩ, (For V _O = 1V to 11V)	25	100		25	100		V/mV	
Common-Mode Rejection Ratio		T _A = 25°C, V _{CM} = 0V to V* - 1.5V	65	85		50	70		dB	
Power Supply Rejection Ratio		V* = 5V to 30V (LM2904, V* = 5V to 26V), T _A = 25°C	65	100		50	100		dB	
Amplifier-to-Amplifier Coupling		f = 1 kHz to 20 kHz, T _A = 25°C (Input Referred), (Note 10)	-120			-120			dB	
Output Current	Source	V _{IN} ⁺ = 1V, V _{IN} ⁻ = 0V, V* = 15V, V _O = 2V, T _A = 25°C	20	40		20	40		mA	
	Sink	V _{IN} ⁻ = 1V, V _{IN} ⁺ = 0V V* = 15V, T _A = 25°C, V _O = 2V	10	20		10	20		mA	
		V _{IN} ⁻ = 1V, V _{IN} ⁺ = 0V T _A = 25°C, V _O = 200 mV, V* = 15V	12	50		12	50		μA	
Short Circuit to Ground		T _A = 25°C, (Note 4), V* = 15V	40	60		40	60		mA	
Input Offset Voltage		(Note 7)	9			10			mV	
Input Offset Voltage Drift		R _S = 0Ω	7			7			μV/°C	
Input Offset Current		I _{IN(+)} - I _{IN(-)}	150			45			200	nA
Input Offset Current Drift		R _S = 0Ω	10			10			pA/°C	
Input Bias Current		I _{IN(+)} or I _{IN(-)}	40	500		40	500		nA	
Input Common-Mode Voltage Range		V* = 30 V, (Note 9) (LM2904, V* = 26V)	0	V* - 2		0	V* - 2		V	

LM158/LM258/LM358/LM2904



Appendix F: Parts Listing and Sources

All components (next page) used in the Industrial Control experiments are readily available from common electronic suppliers. Customers who would like to purchase a complete kit may also do so through Parallax. To use this curriculum you need three items: (1) a BASIC Stamp II module (available alone, or in the Board of Education

- Full Kit); (2) a Board of Education (available alone or in a Board of Education Full Kit); and 3) the Industrial Control Parts Kit.

Board of Education Kits

The BASIC Stamp II (BS2-IC) is available separately or in the Board of Education Full Kit. If you already have a BS2-IC module, then purchase the Board of Education Kit. Individual pieces may also be ordered using the Parallax stock codes shown below.

Board of Education – Full Kit (#28102)

Parallax Code#	Description	Quantity
28150	Board of Education	1
800-00016	Pluggable wires	10
BS2-IC	BASIC Stamp II module	1
750-00008	300 mA 9 VDC power supply	1
800-00003	Serial cable	1

Board of Education Kit (#28150)

Parallax Code#	Description	Quantity
28102	Board of Education and pluggable wires	1
BS2-IC	Pluggable wires	6

This printed documentation is very useful for additional background information:

BASIC Stamp Documentation

Parallax Code#	Description	Internet Availability?
27919	BASIC Stamp Manual Version 1.9	http://www.stampsinclass.com
27341	Industrial Control Text	http://www.stampsinclass.com

Appendix F: Parts Listing and Sources

The Industrial Control experiments require the Industrial Control Parts Kit (#27340)

Similar to all Stamps in Class curriculum, you need a Board of Education with BASIC Stamp and the Parts Kit. The contents of the Industrial Control Parts Kit is listed below, broken down by experiment. Replacement parts in the kit may be ordered from <http://www.stampsinclass.com>.

Industrial Control Parts Kit (#27340)

Stock#	Description	#1	#2	#3	#4	#5	#6	Total/Kit
150-01020	1K ¼ watt resistor		2					2
150-01030	10K ¼ watt resistor	1	2					2
150-02210	220 ohm ¼ watt resistor	1	2					4
150-04710	470 ohm ¼ watt resistor			2	2	2	2	4
152-01031	10K ¼ watt multi-turn pot	1	1	2	2	2	2	2
201-01050	1uF capacitor			1	1	1	1	1
201-01060	10uF 10V capacitor				1	1	1	1
350-00001	LED green	1	1					1
350-00006	LED red		1					1
350-00007	LED yellow		1					1
350-00017	IR Led w/ shrink tube		1					1
350-00018	Infrared Phototransistor		1					1
400-00002	Pushbutton	1	2					2
500-00001	2N3904 Transistor			1		1	1	2
602-00015	LM358 Dual Op-Amp				1	1	1	1
700-00039	35 mm Black Film Canister		1	1	1	1	1	1
700-00040	12 VDC Brushless Fan		1	1	1	1	1	1
800-00027	LM34 Temperature Probe				1	1	1	1
800-00028	47 Ohm Resistor Heater			1	1	1	1	1
ADC0831	ADC 0831 8-bit A/D converter					1	1	1